An EVALUATION of BIOENGINEERING MIETTE ROAD
Jasper National Park

compiled by

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for

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SUMMARY

Bioengineering Test Results

Nine bioengineering techniques applied to 4 sites on the roadside embankments of the Miette Hot Springs road were evaluated for shoot development, erosion control, and early plant growth.

Technique	Plant Material	Success
Brushlayer	cuttings	poor/fair
Hedge Layer	rooted transplants	excellent
Hedge/Brushlayer	cuttings/transplants	v.good
Brush Wattles	cuttings	poor
Wattle Fences	cuttings	poor
Live Staking	cuttings	poor
Cordon-Couturier	rooted transplants	excellent
Cordon-Praxl	cuttings	poor

Techniques that included rooted transplant stock produced excellent results by the end of the second season with many plants reaching a height of 30-45 cm and some plants as high as 100 cm. Two species, wild rose and saskatoon, flowered and produced edible fruit by the end of the second season.

Fall installation produced better results than the spring installation. The spring installation in this study was undertaken after leaf buds had broken and could be a major reason for the poor rooting results observed in techniques that utilized unrooted stem cuttings.

Young (2-3 year old) stem cuttings had better rooting performance than cuttings older or younger. There appeared to be variability in rooting within species, possibly between individual plants.

Bioengineering techniques that utilized unrooted stem cuttings had the best performance at sites with ground water seepages. Results were better on slopes with a north aspect than on those with other aspects. Stem cuttings rooted from stems buried within 5-10 cm of the soil surface. Stem cuttings buried deeper than 10 cm failed to develop roots.

SUMMARY

Seeding Test Results

Five revegetation products were evaluated on the Miette Hot Springs road. The products were installed by the manufacturer and/or distributors. The products were evaluated for plant diversity and ground cover. The products and results are as follows.

Treatment	Diversity	Cover
Humagro	unacceptable	acceptable
Biosol	unacceptable	acceptable
Nitrozyme	acceptable	unacceptable
Biofabric	unacceptable	unacceptable
Hydrated Seed	acceptable	acceptable

Differences between sites could alone account for the success or failure of any of the products. These include soil type, slope length, steepness, aspect, soil moisture level, seed mixture, seeding rate, slope instability, and date of treatment application.

There was not enough evidence to suggest that any of the revegetation products evaluated were necessary for the acceptable results that were observed.

Hydroseeding was a successful method for establishing grass seedlings on the road cuts above the Miette Hot Springs Road.

None of the treatments appeared to mitigate low soil fertility for more than one growing season.

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Bioengineering Tests Contractor

The bioengineering tests were installed by Mr. Bruce McTavish of Northwest Native Plants under contract to Public Works Canada. Our thanks to Bruce for his discussions and time.

Bioengineering Tests Field Supervisor

The installation of the bioengineering tests were supervised in the field by Tera Environmental Consultants (Alta.) under contract to Public Works Canada. Our thanks to Mr. Mark Hagles of Tera for generously providing information.

Seeding Tests Product Distributors

The operational seeding tests were installed by the distributors of the various revegetation products. All representatives of the companies distributing the products were very helpful in providing information on the composition and application of their products. Our appreciation to Mr. Jacob Vanderschaaf of Prairie BioChemicals, Dr. Brian Carpenter of Advanced Growth Systems, Mr. Ken Salamandick of Can-Green Services, Mr. Noel Winter of Proseed Inc., and Mr. Ken Haugen of CEDA Manufacturing & Sales.

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Weather Data

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PART 1
BIOENGINEERING TESTS

1.1 INTRODUCTION

A test and demonstration of bioengineering techniques for revegetation of steep road embankments was installed by Public Works Canada on the Miette Hot Springs Road, Jasper National Park. The Canadian Parks Service contracted the services of David Walker & Associates Limited to evaluate the revegetation success of the test. This section reports on the success of the techniques described below:

Table 1. Bioengineering Tests: Technique Descriptions

Technique	Woody Plant Material
Brushlayer	local, native, unrooted cuttings
Hedge Layer	off-site, native, rooted transplants
Hedge Brushlayer	combination of both above
Brush Wattles	local, native, unrooted cuttings
Wattle Fences	local, native, unrooted cuttings
Live Staking	local, native, unrooted cuttings
Cordon-Couturier	off-site, native, rooted transplants
Cordon-Praxl	local, native, unrooted cuttings

The bioengineering tests were installed by a private contractor during June 1987 and again in fall 1987.

The bioengineering techniques are described in detail by Schiechtl [1] and Gray and Leiser [2].

Revegetation by bioengineering is an attractive choice for National Parks. The various bioengineering techniques utilize locally collected plant materials thereby avoiding the problem of introducing foreign plants, diseases, or pests into the Park. Bioengineering can generally be designed, contracted, and completed within a single season thereby assuring prompt action and results. In contrast, container-grown transplants of native shrubs can take 2-4 years to be installed.

[1]Schiechtl, H. 1980. Bioengineering for land reclamation and conservation. University of Alberta Press, Edmonton. 404 pp.
[2]Gray, D.H. and A.T. Leiser. 1982. Biotechnical slope protection and erosion control. Van Nostrand Reinhold. 271 pp.

1.2 METHODS

1.2.1 Greenhouse Study

Two wattles (fascines, bundles of shrub cuttings) were retrieved from the Miette construction site on June 19, 1987 and taken to Edmonton as samples for a greenhouse study. The samples were taken apart for measurements and then re-assembled. The samples were planted on June 20, the same day other wattles destined for Site #6 on the Miette road were planted. One wattle was planted in a greenhouse using an artificial rooting media commonly used for rooting shrub cuttings. The rooting media consisted of a 50:50 mixture of perlite and vermiculite. The other wattle was planted in a vegetable garden. Both were thorougly watered (as were the wattles at the construction site at Miette) and then monitored weekly for shoot emergence. After 60 days the wattles were excavated and examined for root and shoot development.

1.2.2 Bioengineering Test

The test plot sites were examined on the following dates:

Year	Month	Date	After (mo)
1987	June	17-19	7
	July	11-12	8
	July	28	8
	August	26-27	9
	September	28-30	10
1988	July	9	20
	August	29-30	21
1989	October	4	35

At each site, each row of each technique was examined for shoot development. Plant species were identified and the number of shoots per linear meter of treatment were recorded. Growth was measured in treatments that had rooted shrub transplants.

1.3 RESULTS

1.3.1 Background

Bioengineering depends on successful vegetative plant propagation under natural (field) conditions. Plant propagation by vegetative means has been well studied because there is considerable economic incentive for multiplying plants for horticultural or agricultural applications. Despite extensive research, the reasons for how and why roots develop is still poorly understood.

A review of literature on vegetative plant propagation revealed that several factors control root development besides edaphic or climatic conditions[3]. This suggests that good site conditions do not necessarily guarantee success.

Redwood National Park in California has had extensive experience with bioengineering. Some installations date back to the 1930's and more recent experiences in the late 1970's have been documented. In summary, the Redwood results [4] are:

- Bioengineering techniques often proved unsatisfactory for revegetation and erosion control and have now been substituted by mulches for immediate erosion control and other revegetation methods for long-term erosion control.
- Unrooted stem cuttings of species easy to root (ie. willow species) often had initially high rooting and survival rates but these declined on all sites except immediate streamside sites.
- Wattles of species easy to root (willows) had high initial success but vigour declined in subsequent years on all but the wettest sites. Wattles grew well on wet, northern exposures with fine-textured soils. Wattles also did well close to springs or streams.

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[3]Hartmann, H.T. and D.E. Kester. 1975. Plant Propagation Principles and Practices Third Edition. 622 pp.

[4]Hektner, M.M. et al. 1987. A review of the revegetation treatments used in Redwood National Park 1977 to present. Paper delivered at Biotechnical Slope Protection and Erosion Control Course presented by University of Wisconsin at Vancouver, British Columbia, July 15-17, 1987. 7 pp.

1.3.2 Treatment Descriptions

Table 2 contains a list of bioengineering techniques tested on the Miette Hot Springs Road and costs associated with installation.

Table 2. Bioengineering Tests: Treatment Costs

Technique	Contractor #1	Contractor #2
Brushlayer	$25.69/m	$14.03/m
Hedge Layer	$6.62/m	$10.58/m
Hedge Brushlayer	$26.36/m	$13.70/m
Brush Wattles	$32.70/m	N/A
Wattle Fences	$34.70/m	$24.40/m
Live Staking	$2.15/m	12.10/each
Cordon-Couturier	$23.94/m	N/A
Cordon-Praxl	$20.21/m	N/A

Contractor #1: actual time monitored June 87, figures from Public Works Canada
Contractor #2: bid price for work done in 1989, figures from Public Works Canada.

The Hedgelayer, Hedge Brushlayer, and Cordon-Couturier techniques include rooted nursery stock that must be ordered in advance.

Bioengineering treatments are generally applied in rows 2-4 meters apart but local conditions usually dictate density and position of rows.

1.3.3 Site Descriptions

Considerable variation exists between sites in terms of factors important for plant rooting and growth.

Sites #6 and #28 were the driest and therefore most difficult upon which to establish and maintain vegetation. Sites #10 and part of #22 had ground water seepages that greatly improved rooting and growth of cuttings.

Slopes with a northerly and easterly exposure were in shade most or all of the day; the cool moist conditions created by this exposure were excellent for promoting rooting of stem cuttings in the various bioengineering techniques.

Table 3. Site descriptions of the bioengineering test plots.

Site Number	Slope Aspect	Slope Angle	Soil pH	% Rock Cover	Soil Moisture	Pre-exist Vegetation
6	SW	34°	N/A	15%	v. dry	nil
7	NE	42°	8.1	20%	moist	moderate
8	NE	37°	8.1	35%	moist	moderate
10	N	27°	8.0	10%	wet	moderate
13	NNE	27°	8.1	<10%	moist	abundant
15	NNE	34°	8.1	10%	moist	abundant
21	E	40°	8.1	N/A	dry	moderate
22	NE	37°	8.2	25%	moist	nil
28	SSE	44°	8.2	<10%	v. dry	moderate

1.3.4 Wattle Dimensions

Two wattles (see sec 1.2.1) from the spring 1987 installation were measured for dimensions that might provide information important for explaining the results. The two sample wattles had the following characteristics:

Table 4. Characteristics of wattle bundle samples.

Characteristic	Sample: #1	#2
weight	14 kg	15 kg
average length	2 m	2 m
circumference	82 cm	85 cm
average diameter	26 cm	27 cm
number of stems	23	21
stem diameter min	3 mm	3 mm
stem diameter max	6 mm	5 mm
total stem length	46 m	42 m

The two wattles retrieved from the construction site for the greenhouse study were typical of the plant material and handling methods employed by the contractor who took exceptional care in handling the plant material. The dimensions of the two sample wattles were very consistent. Using the measurements of the samples, the average total length of stem material installed for the wattle technique was calculated.

Material Input — Wattle Treatment
22 metres of stem cuttings per lineal metre of treatment.

1.3.5 Greenhouse Study

The two sample wattles were planted in artificial rooting media in a greenhouse and in black loam in a vegetable garden. The wattles were monitored for shoot and root development over a 60 day period. Results are contained in Table 5.

Table 5. Root/shoot production in wattle samples.

Parameter	Greenhouse	Garden
Days to 1st shoot emergence	20	40
Number stems with shoots	9	3
Total number shoots	23	13
Average length shoots	6 cm	13 cm
Min diameter stem with shoot	12 mm	30 mm
Max diameter stem with shoot	38 mm	50 mm
Total number root clusters	6	0
Number shoots/linear m	4.5	1.5
Total length of stems in each wattle	44 m	44 m
Average number of shoots/meter of stem	0.5	0.3

The results are an indication of the best that might be obtained because of the near optimal conditions for root and shoot development; less success is expected under the field conditions at Miette. Later emergence and fewer shoots in the garden compared to the greenhouse are probably the result of lower average soil temperature. Very few roots developed in the greenhouse and no roots developed in the garden. The poor root and shoot development could possibly be due to the fact that cuttings were taken during a period of active plant growth. The greenhouse results accurately predicted the low number of plants from wattles installed in the field.

1.3.6 Bioengineering Tests

Spring 1987 Installation

Results of the evaluation after the 2nd season of the bioengineering treatments installed in the spring of 1987 are contained in Table 15.

Transplant Treatments

Treatments which included rooted transplants were very successful. These included hedge layering, hedge brushlayering, and Cordon Couturier treatments had the best success in establishing plants. Few transplants appeared to winter kill and a significant number of Canada buffaloberry *(Shepherdia canadensis)* transplants that had been scored as dead in the fall evaluation were observed to have recovered this spring.

Cutting Treatments

Bioengineering treatments that incorporated shrub cuttings performed poorly. Wattle treatments (stems laid parallel) generally were worse than layering treatments (stems jutting out of the slope). Wattling was least successful with 0.17-.0.27 shoots/m. Live staking was also low at 0.16-0.35 shoots/m.

Change from 1st to 2nd Season

There was little change in percent survival or shoots/meter between the evaluation after the 1st season and after the 2nd season. The decline that was observed was due to minor slope failures and debris flows from above. It appears that if cuttings have not rooted by the end of the 1st growing season, a dormant winter season does not improve the chances of rooting next year.

Date of Installation

An unusually early spring in 1987 resulted in the bioengineering test being installed after leaf buds on trees and shrubs had broken, thereby greatly decreasing rooting success. Because the date of bud break is hard to predict from year to year, a fall installation might be a more reliable choice than spring.

Table 6. Evaluation after 2 seasons of shoot development, bioengineering tests, spring installation.

BIOENGINEERING TECHNIQUE	SITE NO.	SURVIVAL (%) TRANSPLANTS	1ST SEASON SHOOTS/METER	2ND SEASON SHOOTS/METER
BRUSHLAYER	8 10(1) 10(2)		1.91 re.installed N/A	1.86 0.01 0.27
HEDGE LAYER	10(1)	100	4.81	3.79
HEDGE BRUSHLAYER	8	65	0.68	1.73
BRUSH WATTLES	6		0.26	0.17
WATTLE FENCE	8 22(N)		0.15 0.28	0.27 0.05
LIVE STAKING	8 22(N)		0.35 0.16	N/A N/A
CORDON-COUTURIER (rooted transplants)	8 10(2) 10(3) 22(S)	82 70 50 67	4.30 5.00 1.39 1.11	2.29 3.50 1.50 1.79
CORDON-PRAXL	22(N) 22(S)		0.74 1.64	0.53 1.16

Fall 1987 Installation 1st Season

Results of an evaluation after 1 season of the bioengineering tests installed in fall of 1987 are contained in Table 7.

Transplant Treatments

Treatments which included rooted transplants showed strong performance similar to that observed in the spring 1987 installation. Survival of transplants was generally high ranging from 25% to 92% (both high and low were observed at site #28).

Cuttings Treatments

Treatments using cuttings performed much better in the fall installation than the spring installation. The best results were from site #13 where brushlayering averaged more than 18 shoots/meter.

Variability of Rooting

Considerable variation in shoot development was observed. Some sections of a row had many shoots while other sections were poor. The most likely reason for the variable results was that some individual plants taken as cuttings rooted better than others thereby resulting in clusters of good and bad results. This could be mitigated by mixing cuttings from several plants before installation.

Soil Moisture

Groundwater moisture appeared to have had a significant effect on success of the bioengineering techniques. Shoot growth was excellent near groundwater seepages. Drier locations at these same sites were generally poor.

Depth of Emergence

Shoots were always found on stems that projected from the ground or were within a couple of cm from the soil surface. It appeared as though shoots could not penetrate the crust that formed on the soil or else shoot development did not occur unless the stems were exposed to air or light. Another observation was

that shoot development was found primarily on intermediate sized stems (ie. 3-6 cm in diameter).

Stripping Leaves

Stripping leaves from stems prior to installation produced a mixed response. At Site #10, subsite #1, there were less shoots (6 per 15 m) on stems which had had the leaves stripped than on stems which had been left intact (12 per 15 m). On Site #22 north, leaf stripping resulted in 29 shoots compared to 17 shoots for intact stems. Pruning back to soil level (as was done for 2 m at site#13 did not appear to increase the number of shoots that developed.

Stripping stems to 1-2 leaves should help rooting by reducing the leaf area and hence moisture requirements until a root system has developed. It is not know why stripping leaves produced mixed results. Perhaps there was mechanical damage to the stems when the leaves were stripped after installation.

Test Plot Results

A test plot of cuttings from one, two, and three year old wood was installed on site #13 at the same time as the fall bioengineering installation. A randomized, ten replicate test consisting of three cuttings of each age class of wood per replicate was installed.

The results indicated that one year old wood did not root well under field conditions (3.3%) while two and three year old wood rooted almost equally well (37% and 43% respectively). Two and three year old wood ranged in size from small finger to thumb size in diameter (12 to 25 mm).

The high rooting rate of selected plant material suggests that less material of high quality might reduce labour costs and increase the success of the treatments. Plant material was selected from stems of young age (1-3 years old) and originating from near the base of the parent plant. (ie. from the root.). Regrowth areas such as a power line right-of-way is expected to produce the best material.

Table 7. Evaluation after 1 season, bioengineering tests, fall installation.

BIOENGINEERING TECHNIQUE	SITE NO.	PLANT MATERIAL	COMMENTS	SHOOTS /METER
BRUSHLAYER	13	local willow cuttings	best results, all sites or treatments	18.61
	15			11.19
	28		poor results entire site	0.53
HEDGE LAYER			not applied fall installation	
HEDGE BRUSHLAYER	7	transplants 52% alive	cuttings 10 stems/m, rooted 1/m	11.03
	13	transplants 60% alive		13.65
	15	transplants 59% alive		3.12
	21	transplants 52% alive		0.70
	28	transplants 25% alive	slope failure killed transplants	1.33
BRUSH WATTLES	13	willow cuttings	excellent results	4.85
	15			3.44
	21			2.44
	28			0.76
WATTLE FENCE	13	willow stakes root	soil crusting produced poor results	0.90
	21	willow stakes root	good results due to stakes rooting	2.30
	28	willow stakes root	entire site poor results	0.22
CORDON-COUTURIER	28	Rw, Ec, Aa	survival 92%	2.75
CORDON-PRAXL	15	willow cuttings	density 10 stems/m	0.00

1.3.7 Species Evaluation

Two techniques included 6 species of rooted nursery stock: Hedge Layer and Cordon-Couturier. Average survival is listed below.

Table 8. Average survival of rooted nursery stock.

Name: Scientific	Common	% Alive
Rosa woodsii	Wood's Rose	97
Elaeagnus commutata	wolfwillow	99
Amelanchier alnifolia	Saskatoon	99
Alnus crispa	green alder	95
Salix scouleriana	willow	96
Shepherdia canadensis	Can. buffaloberry	5

With the exception of Canada buffaloberry, the shrub transplants had a high rate of transplant survival. Numerous Saskatoon plants flowered and later produced fruit. The rose transplants in particular, established and grew very quickly with some exceeding 30 cm by the end of the season. More observations are required to determine the long-term survival of the rooted transplants.

The nursery stock was delivered to the site in several different kinds of containers. The rose and Saskatoon arrived in 1 gallon pots, the alder and wolfwillow were grown and delivered in 175 ml (Hillson size) tree seedling containers (manufactured by Spencer-Lamaire Industries), and the Canada buffaloberry was field grown at the nursery and shipped with the root ball wrapped in burlap. The ball and burlap method appears to have had an adverse effect on survival of Canada buffaloberry.

Fall 1987 Installation 2nd Season

Many of the bioengineering sites were seeded over in the spring of the first season (1988) by the hydroseeding method (Sites #7, #.10, #13, #15, #21, #22, #28) Installation of bioengineering created a rough surface and many microsites for seeds to catch. Even where shrub rooting was poor, the grass catch was good and by the end of the second season, vegetation cover was substantial.

Rooted material in the Hedge Layer, Hedge Brushlayer, and Cordon-Couturier treatments had excellent growth by the second season. Many plants were 30-45 cm in height and some individual plants were 1 m in height (at Site #8). Mortality of rooted transplants was very low between the first and second seasons.

Saskatoon and rose transplants flowered and bore fruit at several of the sites by the end of the second season.

The live stakes that appeared to be taking root died off (Site #13). Wattles at Site #21 that appeared to root and grow during the first season appeared dead after the second season.

Site # 13 had the best results from the rooting of cuttings in the Brushlayer technique.

Many of the slopes were unstable with localized slumpages and debris flows (Sites #1, #7, #10, #15, #28).

1.4 CONCLUSIONS

Rooted Transplants

Rooted plant material produced excellent results.

Installation Season

Fall installation produced better results than spring installation. Bioengineering projects that are large and require several weeks to construct should be scheduled for fall rather than spring. In spring, construction before the soil thaws is generally very difficult. Construction after leaves have flushed on the shrubs is not advisable because stem cuttings generally lose the ability to root if cut during active growth. The short period of time between soil thaw and leaf flush in northern and mountainous regions may preclude all but the shortest construction schedules.

Quality of Cuttings

Young wood (2-3 years old) and of intermediate diameter (12-50 mm) appears to root most readily. Harvesting young wood from areas that have been recently cleared can be expected to produce the best results. Some plants within a species (ecotype, genotype) root better than others. This problem can be mitigated somewhat by thoroughly mixing cuttings taken from different plants so that wood from several plants (and source locations) are together. This is to improve the chances of getting stems that will root.

Site Selection

Unrooted stem cuttings rooted most successfully on sites with moist soil located on groundwater seepages or on the edge of streambanks. North facing expsoures were best with east, west, and south facing slopes next in decreasing order of success.

Planting Depth

Plant material that rooted successfully in this evaluation was close to or at the soil surface. Construction efficiency could be improved by shallow burial of cuttings or by avoiding techiques that bury stem cuttings deeper than approximately 15 cm such as the Brush Wattle technique.

PART 2
SEEDING TESTS

2.1 INTRODUCTION

Five products or product-systems for revegetation were tested on the side-cuts of the newly reconstructed road to the Miette Hot Springs in Jasper National Park. The objective of this study was to report on the various products in terms of effectiveness for promoting revegetation success. The products, their distributors, and a brief description of the products are in the following table:

Table 9. Seeding Tests: Product Descriptions

Distributor	Product	Description
Advanced Growth Systems	Hydrated Seed	seed treatment for faster germination
Can-Green Services	Biosol Frisol Terraveste	organic fertilizer soil amendment soil stabilizer
CEDA-Reactor	Humagro DD 70 & 3608	soil amendment soil stabilizers
Prairie Bio Chemicals	Nitrozyme	growth promoter
Proseed Inc.	Biofabric	roll-out mulch

The Biofabric product has seed imbedded in the mulch mat and was anchored to the ground by wire staples. The other four products were applied along with seed with a hydroseeder.

2.2 METHODS

2.2.1 Test Plot Establishment

The products were installed by the product distributors as demonstrations. Each of the products were applied at several locations chosen by the distributors along the Miette Hot Springs Road. All of the products were established in the fall 1986, except for the Hydrated Seed Treatment and part of the Proseed Treatment at Site #27 which were planted in early spring of 1987. A mixture and rate was specified by Canadian Parks Service.

2.2.2 Data Collection

The test plot sites were examined on the following dates:

Year	Month	Date	After (mo)
1987	June	17	7
	July	11-12	8
	July	28	8
	August	26	9
	September	28	10
1988	July	9	20
	August	29-30	21
1989	October	4	35

At each location, sampling sites were visually chosen which represented the maximum, minimum, and the most common amount of plant cover. Total ground cover at each sampling site was visually estimated with the aid of a 1 m^2 sampling quadrat. Total ground cover was broken down according to the amount of (1) seeded grass cover, (2) herbaceous cover, and (3) bare ground cover. Two sample estimates were made at each sampling site and the results were averaged for reporting purposes. Plant density was recorded and reported as being acceptable (> 10 plants/m^2) or unacceptable. Site descriptions and product data was collected from a number of sources including Public Works Canada internal reports and interviews with the product distributors. Soil analysis data was provided by Public Works Canada. Slope angle was measured with a Suunto Clinometer, aspect was estimated with a standard pocket compass, slope dimensions were measured with a rangefinder.

2.2.3 Data Analysis

Site Variability

A number of factors made direct comparisons between the revegetation products difficult. There were significant differences between sites in terms of physical characteristics such as aspect, incline, stability, and pre-existing vegetation. There were also considerable differences between sites in terms of chemical and physical soil parameters (data in Public Works[5]). Other factors were also present such as the cleat marks in the soil from a tracked vehicle that helped one revegetation product to achieve excellent seedling establishment at one test site.

Assessment

Direct comparisons between the products would be scientifically invalid. To do so might incorrectly indicate that one product is superior to another when in fact the conclusion might be erroneous. Factors other than the products themselves could be responsible for the success or failure of a product at any of the sites. As a consequence, the products have simply been assessed as producing either acceptable or unacceptable results.

An acceptable plant density is defined as at least 10 plants/m2 everywhere that could reasonably support plant growth. An acceptable plant cover is defined as at least 80% ground cover of leaves or dead plant litter (an amount sufficient to substantially control rainfall erosion) everywhere that could reasonably support plant growth. The ground cover value is somewhat transient because plant cover can decline as fertilizer nutrients added at the time of seeding are generally exhausted within 1-3 years. Maintenance of plant cover is not part of this evaluation.

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[5]Public Works Canada. 1986. Slope Studies, Stabilization and Revegetation, Miette Hot Spring Road, Jasper National Park. Internal Report. pp. NA

2.2.4 Supplementary Investigations

Two supplementary investigations were conducted to help clarify the results observed in the Seeding Tests and adjacent rehabilitation seedings. A maintenance application of fertilizer was applied on selected areas on three treatment sites. Samples of seed from bags acquired by the contractor were analyzed for species identification and proportion of each species in the bag.

Maintenance Fertilization

Maintenance fertilization was applied in late June of 1988 (beginning of second growing season). A maintenance application (75 kg-N/ha) of fertilizer was applied to portions of three Seeding Test sites:

Site #22	Biosol
Site #14	Humagro
Site # 9	Nitrozyme

Observations of the effects of the maintenance fertilization were made in fall 1988 and fall 1989.

Seed Mixture Analyses

Samples were taken from sealed bags from bag ends obtained from the contractor. Samples were forwarded to Norwest Soil Research Labs where a certified seed analyst identified the species and proportions of seeds in the samples.

2.3 RESULTS

2.3.1 Site Descriptions

Considerable variation was found between sites with regard to factors important for plant growth (Table 2). A large groundwater seep is located in the middle of Site # 22 (Can-Green, Frisol/Biosol). This provided ample soil moisture and plant growth was consequently very lush at the seep but plant growth was more sparse elsewhere on the same site. Site #27 (Proseed Inc., Biofabric) was observed to be the driest because of the steepness of slope and the southerly aspect. None of the other treatments had such an extreme exposure.

Some sites had inherently eroding (ravelling) slope configurations which no revegetation treatment could be expected to completely stabilize (ie. sites 10, 11, 17, 20, 21, 27, and the road to the old hot-springs).

There was considerable variation between sites with regard to the amount of rocks on the soil surface (see percent rock cover, Table 1). Coarse rock fragments have a negative effect on plant growth when in the soil and also contribute to slope instability by ravelling. Rock can have a beneficial effect on erosion control when on the soil surface by intercepting raindrops and runoff. Many of the sites already had some vegetative cover when the seeding tests were installed and this sometimes made evaluation of the seeding tests confusing.

Table 10. Site descriptions of seeding test plots.

DISTRIBUTOR & PRODUCTS	SITE NO.	SLOPE ASPECT	SLOPE ANGLE	SLOPE EROSION	% ROCK COVER	SOIL MOISTURE	PRE-EXIST VEGETATION
ADVANCED GROWTH SYS. HYDRATED SEED	N/A	NW	33-37	high	20	moderate	moderate
CAN-GREEN SERVICES BIOSOL/FRISOL	1 12 22	W NNE ENE	34 42 25-37	low medium low	40 coal like 35	dry moderate seepage	sparse moderate none
CEDA REACTOR HUMAGRO & DD 70/3608	1 14 19	W NE NNE	20-34 27-37 27-37	low low low	<10 25 25	dry seepage moist	sparse none none
PRAIRIE BIO CHEMICALS LTD. NITROZYME	9 20 21	NE NE E	34 37 37-45	low high high	30 5 25	moderate moderate moderate	sparse moderate moderate
PROSEED INC. BIOFABRIC	17 27a 27b	NNE SSE SSW	35 27-37 22-27	high high low	80 40	moderate dry dry	none none sparse

2.3.2 Product Descriptions

This section contains a description of the products that were applied in the seeding tests. The application rates of the products and the resulting costs are detailed in Table 3. Other components of the treatments, seed mixture, fertilizer, tackifiers, etc. are described on the following pages. A summary of all aspects of product- treatments is outlined in Table 6 at the end of this section.

Table 11. Product costs and installation costs (1986$).

Product	Product ($/ha)	Installed[1] ($/ha)
Hydrated Seed	$180	$3,180
Biosol	$3,000	$6,000
Frisol[2]	$18,000	$21,000
Humagro	$1,727	$4,727
Nitrozyme	$2,876	$5,876
Biofabric[3]	$16,000	$19,000

[1] based on $3,000/ha for hydroseeding (seed/tackifier/mulch)
[2] Frisol includes Terravest tackifier
[3] based on 20 man-days/ha and $150/man-day.

Fertilizer

The presence or absence of fertilizer and the rate of application in each of the treatments varied considerably and this may have had a significant effect on product performance.

Biosol, an organic fertilizer, may be more effective than inorganic formulations if applied during fall because large leaching or volatilization losses of nitrogen have been reported over winter with inorganic fertilizers.

The Nitrozyme treatment did not include fertilizer. Seedlings were observed but growth had not progressed beyond the 3-leaf stage by the end of the first growing season.

Mulches

Mulching can produce mixed results in mountain environments. Inorganic mulches which insulate the soil tend to lower soil temperatures and, when soil moisture is limiting, this can improve plant growth. Mulches can also have a positive affect on plant growth by controlling soil erosion and also by protecting seed from predation by birds and rodents.

When low soil temperature is the limiting factor for plant growth, heavy rates of inorganic mulches can inhibit plant growth. The BioMat product contains a straw mulch at 8,000 kg/ha, a heavy rate by most standards.

Tackifiers

Tackifiers are chemicals which are added to the hydroseeder slurry and function to "glue" the seed and mulch to the ground surface hopefully until seed germination takes place. Four of the five seeding test plots used a tackifier, all different brands. Research results reported in the literature indicate that tackfiers usually reduce plant establishment if good growing conditions prevail. In regions of heavy rainfall, tackifiers are usually necessary to hold seed on sloping ground until germination.

Seeding Date

Seeding date may have some bearing on results. Treatments applied in fall start growth first thing in the spring and therefore have a longer growing season than treatments applied mid to late spring.

Depredation of seed by birds and rodents can be serious in some areas and fall seedings suffer more from this problem than spring seedings.

Seeding Rate

Ground cover increases with seeding rate at least in the first season but can be detrimental in the longer term. At high seeding rates (>500 pure live seeds/m^2), the most aggressive species in the mixture may outcompete the other species and the result may be a monoculture. The stability created by a wide diversity of species in a seed mixture can be lost if the a mix is applied at too heavy a rate.

Parks specifications called for a seeding rate of 100 kg/ha. The Can-Green seed mixture was applied at 300 kg/ha. This rate of application places more than 44,000 seeds/m^2 (see Table 12). Only about 10 plants/m^2 are normally needed to produce an adequate cover.

Seed Mixtures

Canadian Parks Service recommended a seed mix and seeding rate to the product suppliers. Despite this, the seed mixtures varied significantly and similar results in terms of plant cover could not reasonably be expected even on the same site. Table 12 contains the mixture applied by the Can-Green Treatment (the recommended mix but at three times the recommended rate); mixtures used in other treatments are outlined in Table 13.

Perennial Ryegrass

A major factor that affected the results was the rate of application of one species in particular, perennial ryegrass. The species is very aggressive and fast-growing. The presence of perennial ryegrass in a seed mixture in excess of approximately 5 kg/ha will

usually result in a near monoculture at least during the first year. (Can-Green applied perennial ryegrass at 45 kg/ha).

A stand of perennial ryegrass is short-lived however, as the species lacks sufficient winter hardiness in Alberta. When a seed mixture contains a high proportion of perennial ryegrass, the other species must become established under highly competitive conditions. Under these conditions, only the most aggressive species survive the tough competition and a monoculture may result.

Table 12. Seed Mixture Analysis.

Seed Mixture used for the Can-Green Biosol Test Plots

COMMON NAME	SEEDS /GRAM	%/ WT	SEED /M2	%/# SEEDS	EST (%)	PLTS /M2	PLTS (%)
northern wheatgrass	345	20.0	2,070	4.7	23.0	476	12.0
hard fescue	1245	20.0	7,470	16.8	11.0	822	21.0
streambank wheatgrass	344	15.0	1,548	3.5	33.0	511	13.0
Canada bluegrass	5555	15.0	24,998	56.3	2.0	500	12.0
creeping red fescue	1355	15.0	6,098	13.7	13.0	793	20.0
perennial ryegrass	500	15.0	2,250	5.1	40.0	900	22.0
TOTALS		100.0	44,434	100.0	9.0	4,002	100.0

Seed Rate: **300 kg/ha**

KEY TO SYMBOLS

SEEDS/GRAM	number of seeds per gram for each species
%/WT	seed mixture calculated in proportion by weight
SEED/M2	number of seeds of each species planted per square meter
%/#SEED	seed mixture calculated in proportion by number of seeds
EST %	estimated number of seedlings per seed after 1 season
PLTS/M2	estimated number of seedlings per sq. meter after 1 season
%/PLTS	estimated proportion each species of stand after 1 season

Table 13. Seed mixtures for other treatments.

Seed Mixture applied with hydrated seed treatment (Advanced Growth Systems)	
slender wheatgrass	20%
Arctared creeping red fescue	20%
Sodar streambank wheatgrass	15%
annual ryegrass	10%
Reubens Canada bluegrass	20%
sheep fescue	15%

Seed Mixture applied with the Humagro treatment (CEDA- Reactor)	
Spartan hard fescue	20%
pubescent wheatgrass	20%
Sodar streambank wheatgrass.	15%
Reubens Canada bluegrass	15%
creeping red fescue	15%
Fiesta perennial ryegrass	15%
Kentucky bluegrass	?0%
Durar hard fescue	15%

Seed Mixture applied with the Nitrozyme treatment (Prairie Bio Chemicals)	
northern wheatgrass	20%
Durar hard fescue	20%
Sodar streambank wheatgrass	5%
Reubens Canada bluegrass	10%
Boreal creeping red fescue	5%
alpine bluegrass	15%
slender wheatgrass	10%
tufted hairgrass	15%

Seed Mixture applied with Biofabric treatment (PROSEED Inc.)	
Boreal creeping red fescue	25%
Reubens Canada bluegrass	25%
Revenue slender wheatgrass	20%
Climax timothy	15%

Table 14. Summary of the seeding test plot product-treatments.

DISTRIBUTOR & PRODUCTS	SITE NO.	SEED MIXTURE	SEED (kg/ha)	FERTILIZER kg/ha (N-P-K)	TACKIFIER kg/ha	MULCH (kg/ha)	DATE APPLIED
Advanced Growth Systems. Hydrated Seed	N/A	e	not reported	120 (11-48-0)	yes 40 J-Tack	wood fibre 1250	87/6/2
Can-Green Services Frisol/Biosol	1 10/11 22	a	300	2,000 (6-1.5-3.5)	yes Terravest 801 at ?	unknown	86/9/5
CEDA Reactor Humagro DD 70/3608	1 14 19	b	250	750 (16-20-0)	yes 889 kg/ha 942 L/ha	1682	86/9/24
PrairieBio Chemicals Nitrozyme	9 20 21	d	not reported	none	yes ? kg/ha TA2000	yes rate not reported	86/10/16
Proseed.Inc. Biofabric	17 27a 27b	c	90	yes but not reported	no	yes 7600	fall '86 fall '86 87/5/21

2.3.3 Seedling Establishment & Early Plant Growth

Results of an assessment after the first season of seedling establishment and early plant growth are contained in Table 7.

The Advanced Growth Systems "Hydrated Seed" treatment appeared acceptable on a site difficult to revegetate because of the steepness of the slope and repeated disturbances by bighorn sheep.

The Can-Green "Biosol" treatment produced the best overall results of all the products after one season. At Site #1 however, there was no detectable difference between Biosol and Humagro. At Site #22 the excellent results could have resulted from a groundwater seepage. Over 80% of the plant cover on the Biosol sites are due to ryegrass.

The CEDA Reactor "Humagro/Dusdown 70" treatment produced acceptable results. About 50% of the plant cover was due to perennial ryegrass.

The Prairie Bio Chemicals "Nitrozyme" treatment appeared to be a failure. However, seedlings were present in acceptable numbers over most of the sites but plants were very small and under severe nutrient stress.

The PROSEED Inc. "Biofabric" mulch blanket produced unacceptable results. The product appeared to prevent seedlings from emerging through the blanket. The Biofabric (especially the dark colored type) had seedlings only at stress fractures where the blanket had cracked and separated slightly. Ungerminated seed was observed beneath the mulch blanket. The product appeared to also prevent moisture from reaching the soil.

Table 15. Seedling establishment & early plant growth (1st season).

DISTRIBUTOR & PRODUCTS	SITE NO.	MEAN COVER	HERB COVER	COVER UNIFORM	SPECIES DIVERSITY	NUTRIENT STRESS	PLANT DENSITY*
Advanced Growth Sys. Hydrated Seed	N/A	40%	0%	yes	good	no	acceptable
Can-Green	1	20%	0%	no	poor	no	acceptable
Services	12	50%	0%	no	poor	no	acceptable
Frisol/Biosol	22	60%	2%	yes	poor	no	acceptable
CEDA Reactor	1	30%	0%	yes	fair	medium	acceptable
Humagro and	14	25%	0%	yes	poor	high	acceptable
DD 70/3608	19	30%	0%	no	poor	medium	uneven
Prairie	9	<1%	0%	no	good	yes	acceptable
BioChemicals	20	<1%	0%	no	unknown	yes	marginal
Nitrozyme	21	<1%	0%	no	Bioengineering treatment fall 1987		
Proseed Inc.	17	<5%	0%	no	poor	yes	unacceptable
	27a	<1%	0%	no	poor	yes	unacceptable
Biofabric	27b	<10%	1%	no	poor	no	unacceptable

* An acceptaple plant density has more than 10 plants/m^2.

The Can-Green "Frisol" treatment could not be assessed. Areas treated with Biosol and with Frisol were not marked on Site #22. A discussion with the distributor did not reveal information detailed enough to accurately determine where the treatment had been applied. Sampling of Site #22 where both Biosol and Frisol had been applied did not result in any significant difference in plant density or cover. Either the Frisol treatment did not work or was unnecessary for acceptable results that were observed.

Product Assessment

Three of the products produced acceptable results: Hydrated Seed, Biosol, and Humagro. The products are markedly different in composition and purported mode of benefiting plant establishment and growth. Either the three products were able to overcome the same problem each by a different method or else the products were not necessary to begin with. Without control treatments, it is impossible to differentiate between the two possible explanations.

Hydroseeding Success

Hydroseeding was successful as a method of spreading seed and getting seedlings to the 1-2 leaf stage. Even without fertilizer, the Nitrozyme treatment (Sites #9 and #20) had adequate seedling establishment. Plant growth subsequent to the seedling establishment stage appears to depend on soil nutrient availablility. The fertilizer that was included in the three acceptable treatments adequately solved this problem during the first growing season.

2.3.4 Plant Growth After The First Season

The Advanced Growth Systems "Hydrated Seed" treatment appeared acceptable. The site on which it was tested is very difficult to revegetate because of slope steepness and repeated disturbances by bighorn sheep. It was not clear whether untreated seed could have achieved the same results.

The Can-Green "Biosol" treatment produced overall results marginally better than the next best treatment after the first season. At Site #1 there was no detectable difference between Biosol and Humagro. At Site #22, the good results could have resulted from the mositure supplied by a groundwater seepage. Most of the plant cover was ryegrass the first year and creeping red fescue the next. Species diversity was lowest of all the treatments with 80% of the cover coming from creeping red fescue.

The CEDA Reactor "Humagro/Dusdown 70" treatment produced acceptable results. The species diversity was low in this treatment with creeping red fescue accounting for over 60% of the plants. Streambank and pubescent wheatgrasses accounted for most of the remainder with smaller quantities of Canada bluegrass and a few perennial ryegrass plants present in isolated clumps. The previous year, perennial ryegrass accounted for most of the ground cover.

The Prairie Bio Chemicals "Nitrozyme" treatment appeared to produce unacceptable results. However, seedlings were present in an acceptable density on most of the sites but plants were very small and under severe nutrient stress. The treatment did not include fertilizer and the nitrozyme did not mitigate the lack of soil nutrients. The treatment produced a broad diversity of species with 6 of the 8 species in the mixture being well represented.

The PROSEED Inc. "Biofabric" mulch blanket did not produce an acceptable plant density or cover of vegetation. The area adjacent to the test at site #27 was hydroseeded the year following installation of the mulch blanket . The vegetation established by hydroseeding method was better than that of the Proseed mulch blanket method. This was two seasons after hydroseeding and three seasons after planting with the mulch.

Table 16. Plant growth after the first season (fall 1988 & 1989).

DISTRIBUTOR & PRODUCTS	SITE NO.	PLANT COVER	COVER UNIFORM	SPECIES DIVERSITY	NUTRIENT STRESS	REVEGETATION RESULTS
Advanced Growth Sys. Hydrated Seed	N/A	40%	no v. steep terrain	good	moderate	acceptable (for this site)
Can-Green Services	1	acceptable	no	poor	no	acceptable
	12	acceptable	no	spring 88	hydroseeded	replaced
Frisol/Biosol	22	acceptable	yes	poor	fertilized '88	see Maint. Fert.
CEDA Reactor	1	acceptable	no	poor	moderate	acceptable
Humagro and	14	acceptable	yes	poor	fertilized '88	see Maint. Fert.
DD 70/3608	19	unacceptable	no	fair	high	unacceptable
Prairie BioChemicals	9	acceptable	yes	good spring 1988	fertilized '88	see Maint. Fert.
	20			fall 1987	bioeng.	replaced
Nitrozyme	21				bioeng.	replaced
Proseed Inc.	17	unacceptable	no	poor	high	unacceptable
	27a	< 5%	no	poor	high	unacceptable
Biofabric	27b	40%	no	fair	moderate	unacceptable

2.3.5 Plant Nutrients

In land reclamation, it is common to mitigate low levels of plant nutrients in the soil by applying fertilizers. Fertilizers may be classified broadly as either natural organic or chemical. The natural organic materials are of plant or animal origin; the chemical sources are neither plant nor animal.

Organic Fertilizers

Organic fertilizers, such as Biosol, are often viewed as attractive because an ample supply of plant nutrients are added to the soil along with organic matter. There is also the belief that organic fertilizers release nutrients slowly thereby supplying nutrients only as needed. Thus a multi-year supply is provided. Avoided are excessive uptake or nutrient loss from leaching and denitrification (for nitrogen). Agricultural research has shown this is not the case[6].

Within the first three weeks after application, most of the nitrogen in an organic fertilizer will be released. Furthermore, less than half of the total nitrogen will be released in a form that is available to plants even under the best conditions for nitrification. A multi-year or even a full season release of nitrogen from organic fertilizer does not occur. Furthermore, the amount that does become available is but a fraction of the total amount. Incorporation of organic fertilizer into the soil is important to avoid significant losses through volatilization.

Organic fertilizers such as Biosol and farmyard manure can be useful in that nitrogen is supplied in a form that will not burn young seedlings or transplants at high rates. In addition, organic fertilizers add organic matter which improves the soil tilth and ultimately benefits plant growth.

Biosol has been licensed for use in Canada as an organic fertilizer. The fertilizer formula is 6.0-1.5-3.5 (N-P-K) and the recommended application rate is 2,000 kg/ha.

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[6]Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil Fertility and Fertilizers Fourth Edition. Macmillan Publishing Company, New York. p. 149.

Maintenance Fertilization

The results of maintenance fertilization after two months of the second season are listed in Table 17.

Table 17. Percent ground cover in three product-treatments with and without maintenance fertilization (75 kg-N/ha) in the 2nd year.

Site	Treatment	0 kg-N/ha	75 kg-N/ha
# 9	Nitrozyme	11	30
#14	Humagro	10	45
#22	Biosol	72	100

Plant density at the Biosol Site #22 was adequate at 350//m^2 and the percent total ground cover was also high at 72% (mostly litter from perennial ryegrass which had winterkilled). Maintenance fertilization increased the total ground cover to 100% and increased the height of grass from an average of 15 cm to as much as 100 cm. The cover declined in the third season.

The Humagro Treatment at Site #14 had an adequate seedling density (250/m^2) but poor cover without maintenance fertilizer (10% without vs 45%with). The cover appeared to decline in the fertilized section in the third season.

The Nitrozyme Treatment did not include an application of fertilizer at the time of seeding. While the treatment appeared unacceptable at all three sites, seedlings were observed growing in what appeared to be a state of severe nutrient stress. Seedling counts revealed that an adequate density was present (250-440 seedlings/m^2, average 330/m^2). The maintenance fertilizer application substantially improved the ground cover and demonstrated that the lack of ground cover resulted from a lack of soil nutrients which was not mitigated as was hoped by the addition of Nitrozyme.

2.3.6 Seed Mixture Analysis

Two seed mixtures applied to rehabilitation sites adjacent to the test sites were sampled and analyzed for species identification and proportions in the mixture. The following results were found. (Seed Testing Certificates from Norwest Labs are in the Appendix.)

Table 17. Comparison of seed mixture specifications and analysis of bag contents for the 1986 fall and 1987 spring seeding contract.

Species	In the Specs	In the Bag
northern wheatgrass	20.0%	8.3%
Durar hard fescue	20.0%	19.2%
Sodar streambank wheatgrass	15.0%	14.4%
Reubens Canada bluegrass	15.0%	0.8%
Boreal creeping red fescue	15.0%	23.9%
perennial ryegrass	15.0%	25.8%
Kentucky bluegrass	0.0%	7.1%

The contents of the bag differed greatly from the mixture called for in the specifications or the tag on the bag. The results do not necessarily constitute evidence of fraud; a legimate error may have been made by unskilled labour in the warehouse. Ultimately, however, the seed distributor is responsible for the contents of the bag matching the tag sewn to the bag. In this case they did not match.

Table 18. Comparison of seed mixture specifications and analysis of bag contents— summer '87 seeding.

Species	In the Specs	In the Bag
Reubens Canada bluegrass	19.2%	20.0%
Boreal creeping red fescue	13.1%	12.8
Durar hard fescue	15.6%	17.1%
Sodar streambank wheatgrass	24.8%	22.7%
Revenue slender wheatgrass	23.2%	21.7%
perennial ryegrass	4.0%	4.6%

The contents of the bag closely matched the specifications and the small deviations observed could be explained by the sampling technique or an unavoidable variation in blending of the mixture.

2.4 CONCLUSIONS

The following conclusions were made after two growing seasons.

- Hydroseeding was a successful method for establishing grass seedlings on the road cuts above the Miette Hot Springs Road.

- The Seeding Test results are as follows:

Treatment	Diversity	Cover
Humagro	unacceptable	acceptable
Biosol	unacceptable	acceptable
Nitrozyme	acceptable	unacceptable
Biofabric	unacceptable	unacceptable
Hydrated Seed	acceptable	acceptable

- The Biosol and Humagro Treatments (or the seed mixture /seed rate combinations that were used) produced the least diverse plant cover. In both treatments, there was a near monoculture of perennial ryegrass the first season and a near monoculture of creeping red fescue the following seasons. The Hydrated Seed treatment had the most diverse plant cover probably because of the lack perennial ryegrass in the seed mixture and the modest application rate.

- None of the treatments mitigated low soil fertility beyond the first year. One solution is maintenance fertilization until plants become self-sustaining. Other less acceptable solutions for the Park setting are to (1) add topsoil and (2) establish exotic nitrogen-fixing legumes.

- Contract specifications for the seed mixture were not followed in one of the seedings. One way to ensure quality of seed would be for Parks to order the seed rather than require the contractor to do the ordering. With advanced acquisition, the seed bag contents could be confirmed prior to application.

PART 3
RECOMMENDATIONS

3.1 Bioengineering

Application

Techniques that utilize unrooted cuttings should be used on areas moist with ground water seepage, on the edge of streambanks, or on slopes with a northerly aspect. Sites with dry soil conditions such as slopes with a southerly exposure should be avoided.

Bioengineering techniques that call for unrooted stem cuttings should be installed in the fall. Precise timing is required for spring applications to avoid taking cuttings after leaf flush.

Source of Cutting Material

Young (2-3 year old) unrooted stem cuttings are recommended over larger and older cuttings. Powerline rights-of-way cleared within five years are, for example, an excellent source of material.

Unrooted cuttings should be well mixed so that a diversity of plant material from several plants and cutting locations are used. This is to avoid the possibililty of local populations of plants with genetically controlled, low rooting potential.

Technique Selection

The Hedge Layer, Hedge Brushlayer, and Cordon-Couturier techniques are recommended for best success. All utilize rooted transplants as part of the technique.

The Brushlayer technique is recommended where unrooted stem cuttings are the only plant material available. Live stakes function well for anchoring but are not recommended for revegetation. Wattling is not recommended for sites similar to Miette.

3.2 Revegetation

For successful revegetation in mountain environments obstacles must be overcome such as unstable slopes and lack of suitable rooting medium. The following recommendations for revegetation are made bearing in mind that adverse growing conditions will increase the risk of failure.

Revegetation Methods

Short, steep slopes with a low erosion potential should be revegetated by the hydroseeder method.

Long, steep slopes that are low in soil nitrogen or require a high degree of visual mitigation should be transplanted with nursery-grown, nitrogen-fixing shrubs grown from locally collected seed.

A two-step method of fertilization should be used to promote development of an adequate ground cover. A high phosphate analysis fertilizer should be applied at the time of seeding and then a high nitrogen analysis fertilizer should be applied after germination (mid-July).

Revegetation Products

Valid comparisons between products were not possible because of limitations in the design of the experiment. There are differences between sites which could alone account for the success or failure of any of the products. These include soil type, slope length, steepness, aspect, soil moisture level, seed mixture, seeding rate, slope instability, and date of treatment application.

There was not enough evidence to conclude that any of the revegetation products evaluated were necessary for the acceptable results that were observed.

Seed Mixture Acquisition

The highest quality seed possible can be ensured if Parks were to order the seed rather than requiring the contractor to do the ordering. With advanced acquisition, the seed bag contents could be confirmed prior to application.

PART 4
APPENDIX

4.1 WEATHER PATTERNS

4.1.1 REGIONAL WEATHER PATTERN

The May to September summer climate of west-central Alberta including the Miette Hot Springs area has been described by Powell and MacIver[7]. While the Jasper townsite was the warmest station in the study area (May-September average:15.2°C), Miette was included in the coolest category of high elevation stations (average 9.4°C).

In a similar fashion, precipitation in the region was lowest at Jasper townsite (May-Sep average: 200 mm) while the Miette region was included in the highest category (450 mm) typical of high elevations.

The growing season was defined as a continuous period when mean daily temperatures were above -2.2°C, the value considered to be a killing frost for sensitive vegetation. The frequency of days above -2.2°C was variable for high elevation stations but was approximately 100 days compared to more than 130 days for most of the region.

[7]Powell, J.M. and D.C. MacIver. 1976. Summer climate of the Hinton-Edson area, West-central Alberta, 1961-1970. Northern Forest Research Centre, Canadian Forestry Service. 43 pp.

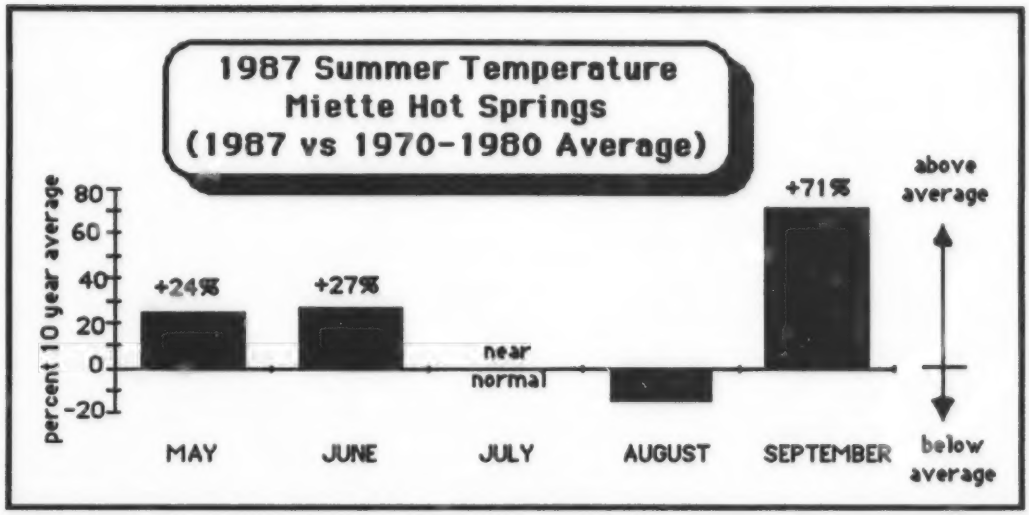
4.1.2 LOCAL WEATHER PATTERN

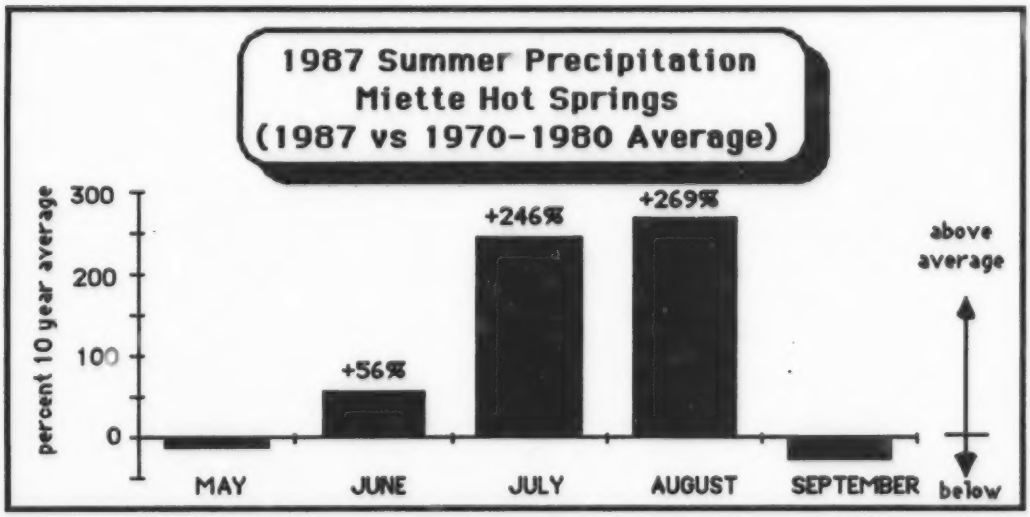
The 1987 summer temperature and precipitation patterns are illustrated in the figures on the following page. The weather at Miette was similar to the general weather pattern experienced by the rest of the province. Spring and fall were warm and dry separated by a somewhat cool but very wet summer.

May and most of June were above average in temperature and below normal in precipitation. July and August were near or below normal for temperature but much above average in precipitation. In particular, precipitation was about 2.5 times the norm in July and August. September was warmer and drier than normal.

The growing season was exceptionally long in 1987. The mean daily temperature did not fall below -2.2°C at any time between May and the end of September.

Precipitation was the most significant weather factor in the 1987 season. The 1987 summer rainfall was more than twice the long-term average (916 mm vs 441 mm). While distribution of rain may not have been ideal, the growing conditions were much above average and plant growth as good as that experienced in 1987 may not occur again for some time.


1987 Summer Temperature
Miette Hot Springs
(1987 vs 1970-1980 Average)
percent 10 year average
80
60
40
20
0
-20
+24%
+27%
near normal
+71%
above average
below average
MAY
JUNE
JULY
AUGUST
SEPTEMBER


1987 Summer Precipitation
Miette Hot Springs
(1987 vs 1970-1980 Average)
percent 10 year average
300
200
100
0
+56%
+246%
+269%
above average
below
MAY
JUNE
JULY
AUGUST
SEPTEMBER

4.2 Seed Mixture for Miette Road (specified by CPS)

Common Name	Seeds/g	PLS	Est %	Seed/m2	Plts/m2	kg/ha	%/wt	Total*
CANADA BLUEGRASS	5555	100	2	10666	213	19.2	19.2	19
CREEPING RED FESCUE	1355	100	12	1775	213	13.1	13.1	13
HARD FESCUE	1245	100	11	1942	213	15.6	15.6	16
STREAMBANK WHEATGRASS	344	100	25	653	213	24.8	24.8	25
SLENDER WHEATGRASS	353	100	26	819	213	23.2	23.2	23
PERENNIAL RYEGRASS	500	100	50	200	100	4	4.0	4
TOTALS				16255	1165	100	100	100

RECOMMENDED VARIETIES	PREFERRED	ALTERNATIVE
CANADA BLUEGRASS	REUBENS	CANON
CREEPING RED FESCUE	BOREAL	DAWSON
PERENNIAL RYEGRASS	NORLEA	MANHATTAN
HARD FESCUE	DURAR	COVAR SHEEP FESCUE
STREAMBANK WHEATGRASS	SODAR	ELBEE NORTHERN WG
SLENDER WHEATGRASS	REVENUE	ELBEE NORTHERN WG

ASSUMPTIONS

1 Mix will be hydroseeded at 100 kg/ha
2 Only recommended varieties or acceptable alternatives used
3 Average 20-40% of seedlings (PLTS/M2) will reach maturity 3 yrs

KEY TO SYMBOLS

SEEDS/G	number of seeds per unit weight (grams) for each species
PLS	Pure Live Seed: percent purity times percent germination
EST %	percent number of seedlings per number of seeds after 1 season
SEED/M2	total number of seeds planted per square metre
PLTS/M2	number of seedlings expected per square metre after 1 season
KG/HA	seeding rate by weight of seed in total and for each species
%/WT	seed mixture calcuated in proportion by weight
TOTAL*	weight of seed of each species and in total to seed 1 hectare

4.3 Analyses of Seed Mixtures Applied by Contractors

Some of roadcuts on Miette Road that were not used in 1987 for bioengineering tests or for seeding test plots were seeded by a contractor in 1988.

Samples of seed were taken from unopened bags using seed sampling tiers. Approximately 500 g in total was removed from 6 bags of 25 kg each. Results of an analysis of the seed mixture in the bags are contained on the page following.

See section 2.3.6 (page 44) for discussion of results.

INTERIOR REFORESTATION CO.
CRANBROOK, B.C.

WT: 25 KG LOT M 2387

"P C"

INTERIOR REFORESTATION SPECIAL MIX

23 20% NORTHERN WHEATGRASS
15 20% DURAR HARD FESCUE
25 15% SODAR STREAMBANK WHEATGRASS
19 15% RUBENS CANADA BLUEGRASS
13 15% BOREAL FESCUE
4 15% PERENNIAL RYEGRASS

CANADA NO. 1 GROUND COVER MIXTURE

SUPPLIED BY: RICHARDSON SEED

4055 McCONNELL DRIVE
BURNABY, B.C. CANADA V5A 3A7

Richardson Seed Company Limited warrants to the extent of the purchase price that seeds sold are as described on the container within recognized tolerances. Seller gives no other warranty express or implied as to the variety, description, quality, productiveness or any other matter of any seeds, and will not be in any way responsible for the crop. If this warranty is not acceptable to the buyer, the buyer must not plant the seed.

NORWEST LABS

9938 - 67 Avenue, Edmonton, Alberta
T6E 0P5
Phone No. 438-5522

SEED TESTING CERTIFICATE

This certifies that a sample of FORAGE MIXTURE

designated 87-3458
was received from

DR.DAVID G.WALKER
WALKER & ASSOC. LTD.
R.R.#1 SOUTH
EDMONTON
ALTA
T6H 4N6

When referring to this sample always quote

CERTIFICATE NO. 87-3458

WEED SEEDS — number per 25 GRAMS

Prohibited noxious: 0

Primary noxious:

Total Primary: 0

Secondary noxious:

Total noxious: 0

Other weed seeds

WINDGRASS	28
RAT'S-TAIL FESCUE	20
CORN SPURREY	4
FORGET-ME-NOT	4

Total weed seeds of all kinds: 56

Sweet Clover number per 25 GRAMS 0

SEEDS OF OTHER CROPS number per 25 GRAMS

ERGOT LESS THAN 1%
WHITE CLOVER TRACE
AGROSTIS SPECIES TRACE
KENTUCKY BLUEGRASS 7.1%

Total

URE SEED	%	OTHER CROP SEEDS	%	WEED SEEDS	%	INERT MATTER	%
ERMINATION	%	HARD SEEDS	%	GERMINATION, INCL HARD SEEDS	%	PURE LIVING SEED	%

REMARKS

THE SAMPLE GRADES

Analysis of listed components

Ryegrass	25.8%
Creeping red fescue	23.9%
Hard Fescue	19.2%
Streambank wheatgrass	14.4%
Northern wheatgrass	8.3%
Canada bluegrass	0.8%

Wild oat (1) found in 3rd quantity
Stinkweed (1) analysed

SENIOR MEMBER OF

COMMERCIAL SEED ANALYSTS ASSOCIATION OF CANADA

66

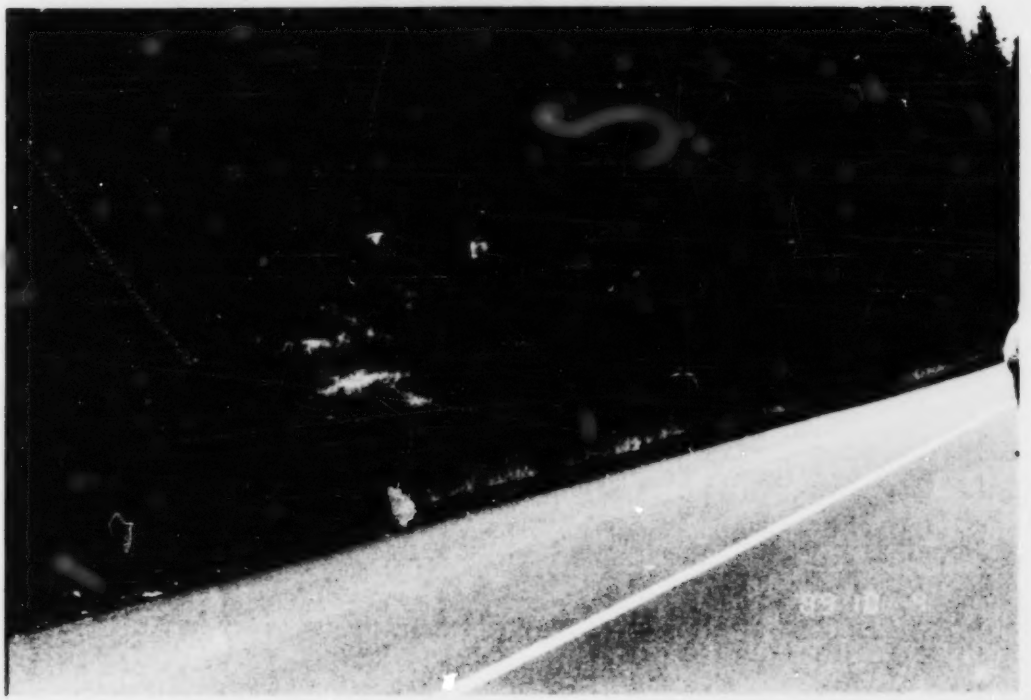
13JUL88 — DATE RECEIVED

20JUL88 — DATE

Cheryl Engler
SUPERVISOR – CHERYL ENGLER

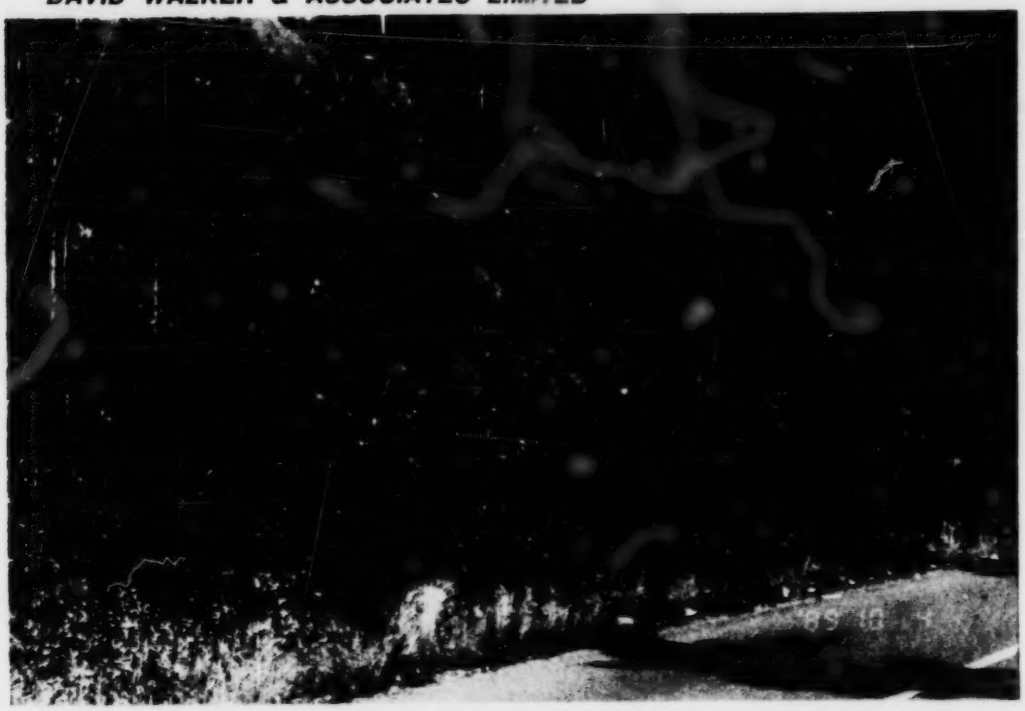
The responsibility for any seed sold under this certificate with respect to grade or any other specification rests entirely with the seller.

PART 5
Photographs

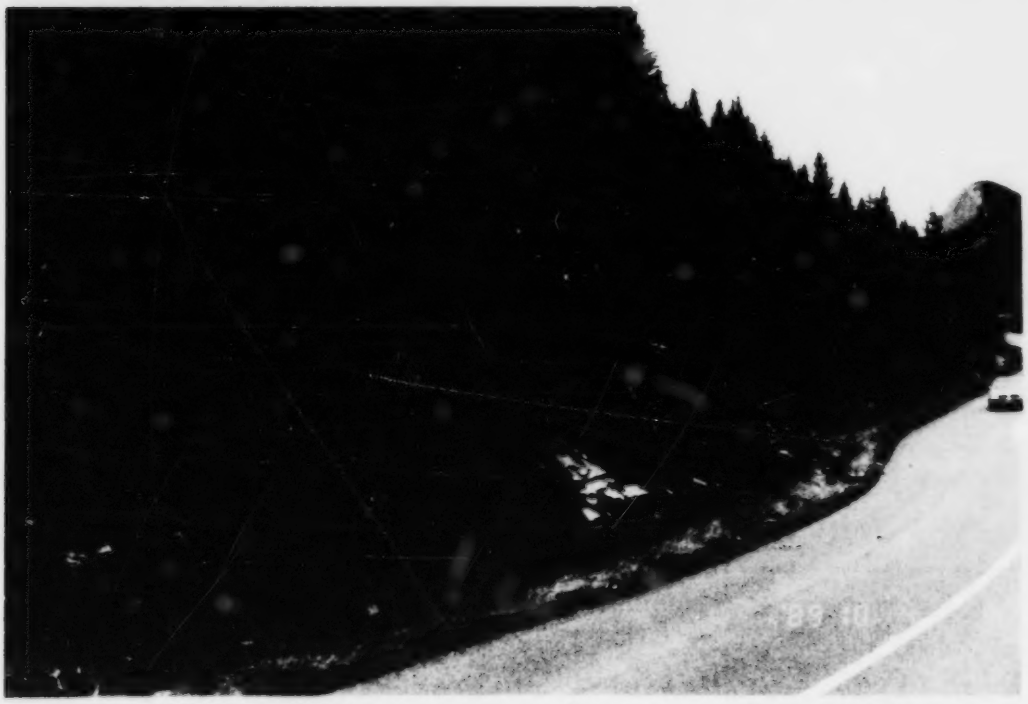


Photograph 1. View of Site # 13 showing good grass establishment and excellent bioengineering installations of brushlayer, hedge brushlayer and brush wattles. Photo taken 2 years after installation, October 1989.

Photograph 2. View of Site # 21 When hydroseeding failed at this site, bioengineering was installed. Upper: brush wattles; lower: hedge brushlayers. Photo taken 2 years after installation, October 1989.



Photograph 3. View of Site # 28 Aspect (SSE), steepness (44°), and slope failures made this site the most difficult to rehabilitate. Bioengineering results from hedge brushlayer excellent for the conditions.October 1989.



Photograph 4. Site # 22 had poor results from a spring installation of bioengineering but grass establishment was acceptable. October 1989.

Photograph 5. Site # 28 treatment with straw mulch banket was not successful in establishing an acceptable cover of vegetation. October 1989.

Photograph 6. View from Ashlar Ridge Lookout . The value of topsoil is clearly illustrated. Left side: no topsoil (pre-existing road), right side: topsoil imported. October 1989.